TECHNOLOGY DIGEST

TD-12-016
©AUGUST 2012

TIMELY TECHNOLOGY TRANSFER

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Seasonality of Wheelset Removals: Analysis of Wheel and Rail Friction

Scott Cummings and Roman Kudinov

Summary

Transportation Technology Center, Inc. (TTCI) conducted an analysis to investigate the relationship between weather and wheel/rail friction conditions as a possible contributing factor for the increased number of wheelset removals each winter in Canada.

Higher friction levels at the wheel/rail interface could reduce the mileage necessary to develop shelling and high impact loads through the process of rolling contact fatigue. The analysis shows that, while winter snowstorms are related to temporary increases in the percentage of wheels exceeding 90,000-pound impact loads, the average wheel/rail coefficient of friction (COF) is lower in the wintertime and decreases temporarily during typical winter storms.

However, winter precipitation that fell at one location as “pellets” allowed relatively high wheel/rail COF to persist, indicating that the theory of snowstorms possibly increasing wheel/rail COF could be applicable in locations where winter precipitation is commonly in the form of pellets rather than snowflakes.

The theory tested in the analysis would require the COF to increase in the winter, possibly from factors such as these:

- Blowing snow may provide sufficient abrasive action on the wheels and rails to remove lubricant or contaminant.
- Wayside lubricators may not function as effectively during periods of extreme cold.

TTCI’s analysis was conducted using data from truck performance detectors (TPD) and wheel impact load detectors. Values of the wheel/rail COF were assumed equal to the 99th percentile of the ratio of lateral force to vertical force (L/V ratio) at wheels on the leading axle of each truck on the low rail side of a TPD curve.

This work was conducted as part of the Association of American Railroads’ Strategic Research Initiatives Program to prevent wheel failures.

Please contact **Scott Cummings (719) 584-0739** with questions or concerns regarding this *Technology Digest.* E-mail: scott_cummings@ttci.aar.com.

INTRODUCTION

The relationship between weather and wheel/rail friction conditions was analyzed as a possible contributing factor for the increased number of wheelset removals each winter in Canada. Increased friction could reduce the mileage necessary to develop shelling and high impact loads through the process of rolling contact fatigue. This work was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program to prevent wheel failures.

BACKGROUND

Winter wheel tread damage is a problem particularly in Canada. As detailed in a previous digest, 58 percent of tread damage wheelset removals in Canada occur during the four coldest months of the year, and the majority of the removals are due to shelling from fatigue, as opposed to flat spots and spalling.[1] The same digest describes several hypotheses that have been presented for this phenomenon:

- Precipitation results in the ingress of water into surface cracks in the wheel, causing accelerated crack growth and material break-out due to either hydraulic pressure[2] or the wedging action of water as it becomes ice.[3]
- Increased use of brakes during winter to remove any snow or ice buildup could result in more wheels reaching temperatures of accelerated shelling.
- Precipitation causes a change in wheel/rail COF in Canada during the winter compared to warmer months. This theory would require the COF to increase in the winter, possibly from factors such as:
  - Blowing snow may provide sufficient abrasive action on the wheels and rails to remove lubricant or contaminant.
  - Wayside lubricators may not function as effectively during periods of extreme cold.

In order to explore the theory regarding seasonal changes in COF, several TPD sites in the United States (U.S.) and Canada were analyzed for differences in COF. TPD sites provide data about the vertical and lateral forces as each wheel in the train negotiates curved track. Figure 1 demonstrates an assumption used in this analysis for the COF between wheel tread and the crown of the low rail in a curve. The plane of the contact patch is nearly parallel with the track surface and so simplifying assumptions are made that the normal force is equal to the vertical force and the friction force is equal to the lateral force. The L/V ratio is limited by the COF. The leading axle in each truck typically has a higher angle of attack to the rail and produces larger lateral forces. Thus, the 99th percentile of the L/V ratio on the leading axle of each truck on the low rail side has been chosen as an appropriate indicator for the COF. This allows (and requires) the use of large quantities of data in determining the assumed COF. The 99th percentile L/V ratio was chosen rather than the maximum L/V ratio to reduce the probability of error due to any electrical "spikes" or other data anomalies.

During the work, several TPD and wheel impact load detector (WILD) data analyses were performed. The data was queried from *Inte*RRIS®[4] and TTCI's internal analysis databases. In order to obtain information about historical snow precipitation and ambient temperature observations, the following weather databases were used: National Climate Data and Information Archive for Canada[5] and National Operational Hydrologic Remote Sensing Center for the U.S.[6]

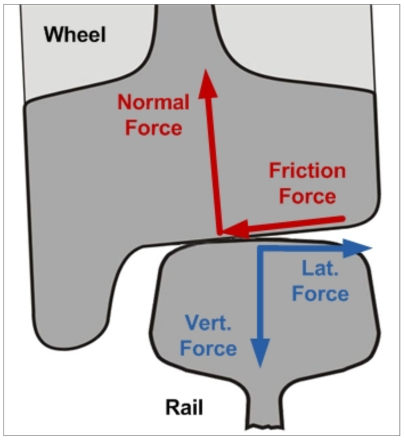

Figure 1. Forces between Wheel and Low Rail

ANALYSIS

The first step of the analysis was to look for any differences in the assumed COF between winter and summer periods. For that purpose, historical statistics for the first and third quarters of the year (winter and summer times respectively) were obtained from four TPD sites in the southern U.S., three TPD sites in the northern U.S., and one TPD site in eastern Canada. No other historical Canadian TPD data was available. The data interval ranges from 2006 to 2011. The percent change of assumed COF was determined between each winter and summer period at each TPD site. TTCI decided to use only the historical data that had at least 30,000 lead axle readings per quarter. The average number of axle records was approximately 190,000 per quarter. The results provided in Figure 2 are presented in the form of percent increase in assumed COF during summer periods. Seven out of the eight TPD sites analyzed exhibited higher average assumed COF in the summer compared to the winter.

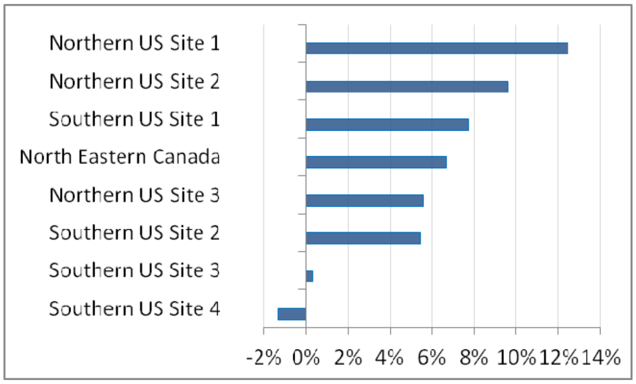

Figure 2. Percent Increase of Assumed COF during the Summer

Although the COF appears to be higher on average during the summertime, this does not rule out the possibility of short term frictional changes associated with specific transient weather events. The next step was to analyze the behavior of assumed COF before, during, and after winter snowstorms. The compiled dataset includes observations of L/V ratios from two TPD sites in the northern U.S. and one in Canada. It contains three individual snowstorm periods for each site in the U.S. and ten snowstorm periods for the Canadian site. Each snowstorm period was analyzed over a 7-day interval where the third day of the interval is the day of the main snowstorm. The snowstorm is determined by the presence of the following two criteria:

- The maximum ambient temperature during the day is 32°F (0°C) or less.
- The total amount of snow precipitation is at least 4 inches (10 cm).

The analyzed data included on average about 650 and 850 lead axle readings per day for empty and loaded cars respectively and never less than 100 empty or loaded records per day. Figure 3 shows the average assumed COF for Canada and the U.S. during these snowstorm periods.

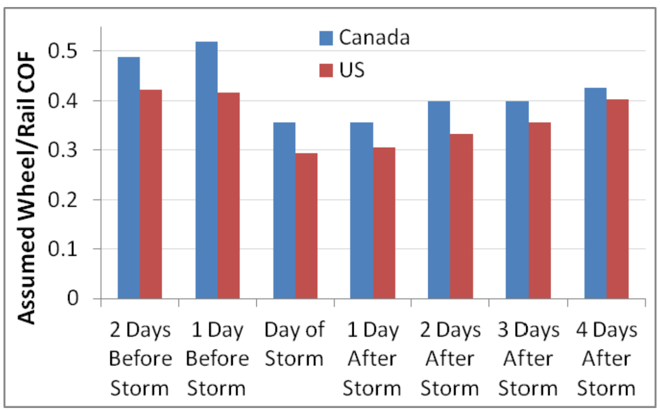

Figure 3. Changes in Assumed COF for Canada and the U.S. during Snowstorms

At all U.S. TPD sites, the assumed COF decreased during each snowstorm. In eight out of ten snowstorm periods at the Canadian TPD, the assumed COF decreased during the snowstorms, while only two snowstorms showed an increase in the assumed COF. One of those two anomalous snowstorms was examined in more detail using hourly snow precipitation data. Data on the day of the snowstorm was divided into two groups based on whether it was recorded before or after the initiation of the precipitation. Figure 4 shows two histograms of the lead axle low rail wheel L/V ratios before and after the start of the snowstorm. The L/V ratios take a similar distribution before and after the snowstorm up to a value of approximately L/V ratio = 0.25. At higher L/V ratios, the distribution is significantly different before and after the snowstorm, presumably due to a reduction in COF from the precipitation.

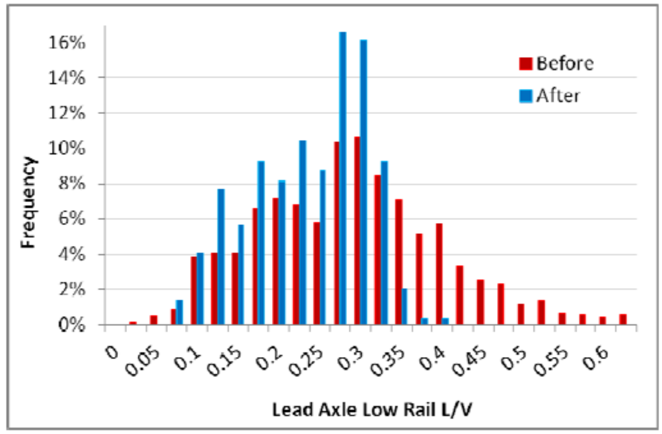

Figure 4. One Day Histogram of L/V Ratios, Before and After the Start of a Snowstorm

Based on the results obtained from the COF snowstorm analysis, TTCI decided to proceed with further investigation by categorizing snowstorms by regular snowstorms and storms with reported precipitation in the form of “snow pellets” or “ice pellets” as described by the National Climatic Data Center.[7]

For the analysis, four regular snowstorms and four ice/snow pellet storms were chosen for one of the TPD sites in the northern U.S. Data was compiled in the same manner as for the snowstorm analysis described previously. Figure 5 shows that the average assumed COF drops significantly during a common snowstorm; whereas, during an ice/snow pellet storm, it changes much less dramatically. Ambient temperatures were similar for both types of storms, typically 20°F (-7°C) on the day of the storm; however, the snowstorms resulted in more than 5 times the total precipitation compared to the pellet storms. The four ice/snow pellet storms analyzed did not cause an increase in the assumed COF, but they also did not produce sufficient moisture at the wheel/rail contact to reduce the assumed COF as observed in the majority of snowstorms.

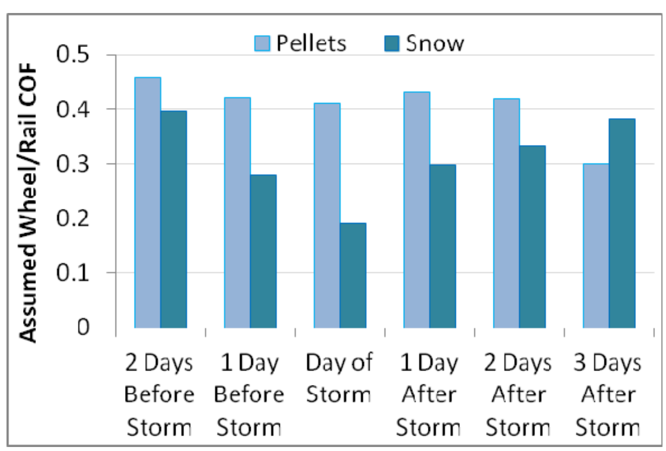

Figure 5. Changes in Assumed COF Due to Type of Precipitation

After determining that a typical winter storm produces a decrease in the assumed COF rather than an increase, the effect of snowstorms on impact loads was evaluated. Data from the WILD sites was analyzed for any behavior of increased impact loads during the periods before, during, and after snowstorms. For that purpose, historical data from *Inte*RRIS® was queried for 10 WILD sites located in the eastern, western, and central parts of Canada and for 2 WILD sites located in the northern U.S. The number of WILD readings available for this analysis was on average about 2,600 and 2,800 wheels per day for empty and loaded cars respectively, and this number was never less than 400 wheels in a day for both car categories. Figure 6 shows a brief increase in the percentage of wheels with impact load higher than 90,000 pounds following a snowstorm in the U.S., whereas the increase is sustained for a longer duration in Canada.

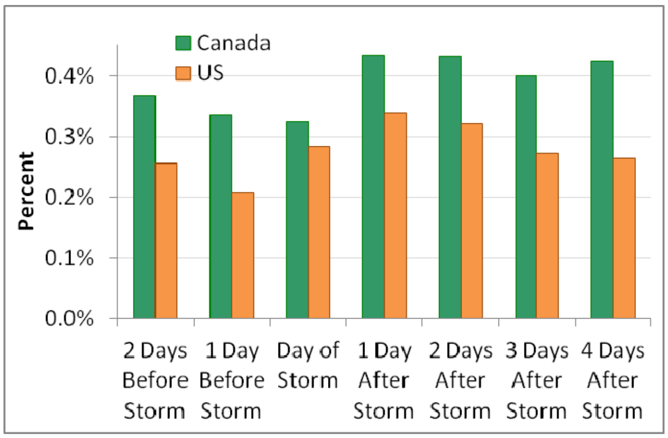

Figure 6. Average Percentage of Wheels with Impact Load Higher than 90,000 Pounds

CONCLUSION

TPD and WILD data were analyzed to investigate the theory that winter snowstorms could produce an increase in the wheel/rail COF and be a major contributor to the winter wheel shelling problem in Canada. Winter snowstorms do cause a temporary increase in the percentage of wheels exceeding 90,000-pound impact loads, but the majority of the effect does not appear to be related to increased wheel/rail traction forces because, in fact, limited study conducted by TTCI shows the wheel/rail COF typically decreases.

Based on TTCI tests and analyses, the following specific conclusions are also made:

- Wheel/rail COF is typically higher in the summer than in the winter.
- Typical winter snowstorms cause a temporary decrease in the wheel/rail COF.
- Typical winter snowstorms cause a temporary increase in the percentage of wheels exceeding 90,000-pound impact loads. This effect appears to be more prolonged in Canada compared to the U.S.
- Winter precipitation that fell at one TPD site as "pellets" allowed relatively high wheel/rail COF to persist, possibly indicating that the theory under investigation could be more applicable in locations where winter precipitation is commonly in the form of pellets rather than snowflakes.

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